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(54) Title: SANDWICH MATERIAL

(57) Abstract

The invention relates to a method for modifying a sheet-like sandwich material comprising a core material provided between two top layers, wherein under pressure an amount of thermoplastic material is injected through one of the top layers into the core material, an object is placed in the still plastic material, whereafter the plastic material hardens.

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Title: Sandwich material

This invention relates to a method for modifying a sheet-like sandwich material comprising a core material provided between two top layers.

Sheet-like materials, such as sandwich constructions, are often used for those applications where high strength or rigidity in combination with a light weight is required. This is the case, for example, in air, space, and transport applications.

Sandwich constructions generally consist of a core material that is light in weight, with a top layer, often reinforced, on both surfaces thereof. Owing to the good bonding between the top layers and the core material, the proper stiffness is obtained. The other properties of the material are partly determined by the nature of the various materials.

Known sandwich constructions are based on a core material having a honeycomb structure. Another type of sandwich material is described in European patent applications Nos. 264,495 and 269,148, the contents of which are incorporated herein by reference. This material is fully thermoplastic and consists of a core material including *inter alia* a thermoplastic foam and two top layers consisting of a fiber-reinforced synthetic plastics material, such as polycarbonate or polyether imide.

U.S. Patent No. 4,889,763 discloses a flame-resistant sheet-like material which is also thermoplastic.

European patent application No. 345,855 relates to a non-foamed film which can be used for the manufacture of a thermoplastic sandwich material.

In the application of a sandwich construction, it may sometimes be desirable that local reinforcements be provided in the material. Sandwich constructions are typically in the form of a plate, for instance a wall panel, to which various objects must be secured. As this may locally involve rather considerable forces, it is necessary to provide local

reinforcement to enable objects, such as auxiliary means, to be secured thereto.

European patent application 383,409 describes a method for providing reinforcements in a preferably thermoplastic core of a sandwich material by injecting under pressure an amount of plastic material through one of the top layers into the core material, which plastic material hardens after injection. This method provides good possibilities for the application of auxiliary means, such as fastening means, brackets, lamp holders, and the like.

Although this method gives a considerable improvement over the known methods, it has been found that it is possible to further improve the properties of the final material by carrying out the arrangement of the object in a specific manner.

The present invention accordingly relates to a method for modifying a sheet-like sandwich material comprising a core material provided between two top layers, wherein under pressure an amount of thermoplastic material is injected through one of the top layers into the core material, an object is placed in the still plastic material, whereafter the plastic material hardens.

Surprisingly, it has been found that with the method according to the invention a sandwich material is obtained which possesses a very good bonding between the sandwich material and the modification arranged.

The modification of the sandwich material can occur in different manners. A first possibility is to provide a reinforcement in which an object is fixedly secured in the manner according to the invention. Through the specific method, a very good bonding is obtained, even in the case where an object of an unusual form is provided. With the known method, in which first the reinforcement is provided and subsequently, after hardening, an auxiliary means is arranged, it is impossible or practically impossible to arrange such objects.

A second variant of the method according to the invention is to arrange an object which is subsequently removed during or after hardening. In that case, the removal should occur after the thermoplastic material has become sufficiently form-retaining. With this method, a modification is manufactured which consists of a reinforcement which is eminently bonded within the sandwich material and which is provided with an opening extending, for instance, all the way through the material or only through a part of the material.

With this method, it is also possible to provide a screw thread in the modification. According to the invention, an object is arranged which is provided with a screw thread on the outside thereof. After hardening of the synthetic material, the object is unscrewed from the modification.

In the embodiment where the object is removed from the modification, it is possible to provide the object with a releasing agent, for instance a silicone compound, prior to its introduction.

A great advantage of the invention is also that it is possible to repair a fastening provision, once it has been arranged, by removing the object arranged and fitting an oversize, new part.

When carrying out the method, it is preferred if the object, at the time of its arrangement in the plastic material, has a temperature which is lower than the temperature of the plastic material of the reinforcement. It has been found that in such a case an optimum bonding of the object in the core is obtained. If this temperature is equal to or higher than the temperature of the plastic material, a lesser but no poor bonding is obtained. More specifically, the object has a temperature which is not higher than 75°C and most preferably not higher than 35°C.

Naturally, the material of the reinforcement should not have hardened yet when the object is arranged in the core. The temperature of the plastic material should be above the softening point thereof, it being noted that it is preferred,

for reasons of applicability under more or less extreme temperature conditions, to use a thermoplastic synthetic material having a softening temperature which is at least 50°C and preferably above 75°C (HDT, according to ASTM D 648-56).

In practising the method according to the invention, at least two steps are carried out. In the first step the plastic material is forced into the core under pressure. The material can be injected directly through the top layer, provided the top layer is suitable for that purpose. Otherwise, first an opening must be provided in the top layer. This may be necessary in particular in the case where one or both top layers are made of metal or any other material that is difficult to penetrate.

During injection, the core material is displaced and/or caused to melt by the plastic material at the place of the injection. In the case where the core of the sandwich material consists of a thermoplastic material, for instance a thermoplastic synthetic plastics foam or a thermoplastic honeycomb material, fusion in particular occurs, as described in European patent application 383,409. If the core material is not thermoplastic, it is displaced by the injected material. With regard to bonding and material properties, it is preferred to use a thermoplastic core material.

Preferably, the amount of material to be injected and the temperature thereof are set such that a part of the core material, more specifically the foam, melts away at the place of the injection.

Subsequently, when the material is still plastic, i.e., when the material is still so warm as to melt under pressure, the object can be introduced into the plastic material. The plastic material flows around the object and hardens practically instantaneously as a result of the lower temperature and heat uptake of the object. According to the invention, it has been found, surprisingly, that through the build-up of pressure in the plastic material considerably less shrink arises, particularly when the object is arranged at the

time when the thermoplastic material at the outside of the modification is already hardening.

As plastic material, preferably a thermoplastic synthetic material or mixture of thermoplastic synthetic materials is used, having a softening temperature of at least 50°C. Such synthetic materials can be selected *inter alia* from the group consisting of polystyrene, styrene polymers, acrylate and/or methacrylate polymers, polyolefins, polyesters, such as PET and PBT, polycarbonate, polyether imide, polyamide, polysulfone, polyether sulfone, polyether ketone, polyether ether ketone, polyether ketone ketone, polyphenylene oxide, polyphenylene sulfide and mixtures of two or more of these synthetic materials. Such materials not only have the advantage of being injectable into the core with facility, but also contribute to the improvement of the pressure resistance of the sheetd-like material.

Optionally, these synthetic materials may contain a quantity of fibers, which are injected along with them. The fibers are preferably selected from the group consisting of glass fibers, polyamide fibers, such as aramid fibers, polyethylene fibers, polyester fibers and carbon fibers.

It is also possible to incorporate a quantity of blowing agent into the synthetic plastics material to be injected, which blowing agent forms a foam from the synthetic plastics material injected, during and after the injection. Naturally, it is then desirable that the amount of foaming agent be such that the density of the modification is greater than the density of the surrounding core material, or that the pressure resistance of the foam formed is greater than the pressure resistance of the core of the sheet-like sandwich material.

It is noted that it is also possible to inject two plastic materials simultaneoulsy, or one after the other. In this connection one could in particular contemplate an injection of two different materials, such that one material forms the core of the injection and the other material forms a kind of skin around it. This can be achieved both by the

simultaneous injection of two or more materials, and by the consecutive injection of the two or more materials. In that case, however, when the object is being arranged, the desired construction of the reinforcement should be taken into account.

The sandwich material to be modified can be structured in different manners. Generally, the material consists of a core and two top layers. The core, in turn, may made of a plurality of layers, for instance reinforcing layers and filling layers.

The core may consist of any suitable core material, such as a synthetic foam which may or may not be thermoplastic, a honeycomb material which may or may not be thermoplastic, or any other suitable material.

As top layers, different materials are eligible. Examples include metal sheets, for instance aluminum, fiber-reinforced synthetic plastics materials and natural materials, such as wood.

The sandwich construction preferably consists of a thermoplastic, foamed, core material and two top layers, which consist of a thermoplastic synthetic material reinforced with a woven fabric, a knitted fabric, a fibrous web or unidirectionally applied fibers. Such a material is described *inter alia* in European patent applications Nos. 264,495 and 269,148, which were mentioned in the introductory part of this specification.

The materials of which the preferentially used sandwich material may be made up are also described in the European patent applications referred to. More specifically, the thermoplastic foamed core material is a polyether imide foam, a polycarbonate foam, a polymethacrylamide foam, a polyester foam, such as a foam of PET or PBT, a polyether sulfone foam, a polyether ketone foam, a polyether ether ketone foam, a polyether ketone ketone foam, a polyphenylene oxide foam, a polyphenylene sulfide foam, or foam materials made from mixtures of thermoplastic synthetic materials incorporating at least one of the thermoplastic synthetic materials mentioned.

It is also possible to use, as core material, a combination of two or more foams.

Optionally, fibers may also be provided in the foam material. Such fibers may be selected from the group consisting of glass fibers, polyamide fibers, such as aramid fibers, polyethylene fibers, polyester fibers, carbon fibers and combinations of two or more of these fibers.

Also, to improve the mechanical properties of the material, it may be preferable to incorporate liquid crystalline materials in the foam. In particular in the case where the foam is generated in situ during the manufacture of the sandwich material, the use of such materials has been found to give good results. When the above foam materials are used in combination with the thermoplastic synthetic materials, to be mentioned hereinafter, for the top layer and the reinforcement, an optimum construction of the reinforcement and a maximum strength of the total construction and of the reinforcement points are obtained.

The top layers preferably consist of fiber-reinforced synthetic material, more particularly of a thermoplastic synthetic material reinforced with a woven fabric, a knitted fabric, a fibrous web, or unidirectionally applied fibers.

The thermoplastic synthetic material, the matrix material of the top layers, is generally a synthetic material or a mixture of synthetic materials having a high softening point, for example polyester, such as PET and PBT, polycarbonate, polyether imide, polyamide, polysulfone, polyether sulfone, polyether ketone, polyether ether ketone, polyether ketone ketone, polyphenylene oxide, polyphenylene sulfide or a mixture of two or more of these synthetic materials. It is also possible to use two or more different top layers or materials for the top layers.

In the top layer, these synthetic materials are preferably reinforced with glass fibers, polyamide fibers, such as aramid fibers, polyethylene fibers, polyester fibers and carbon fibers. The nature of the fiber reinforcement in

the top layer has substantially no influence on the conditions for injecting the thermoplastic synthetic material into the core, but the degree of reinforcement may have an effect on them. In fact, according as the density of the fiber reinforcement in the skin is higher, the more pressure will have to be exerted for injection through the top layer. However, these pressure variations always range within conventional injection molding pressures. In the case of very high densities of the fibers in the skin, it may in certain cases be desirable or advantageous to pre-drill a small hole in the skin.

The sandwich construction can be manufactured by arranging the components, core material and top layers to be used on top of each other, optionally with bonding layers between them, with or without the use of softening agents, and subsequently bonding the layers together by applying heat and pressure.

When a foamed core material is used, it is also possible to generate the material in situ by using an expandable material which foams and bonds to the top layers upon heating and/or reduction of the pressure. An example of such an expandable material is described in European patent application 345,855, the contents of which are incorporated herein by reference. This material can be used for both the core material and an additional bonding layer. It is also possible to use the known thermosetting foam materials.

The first step of the method according to the invention is quite simple to perform utilizing existing equipment. In fact, when an injection molding machine is used, one only has to move the nozzle thereof to the place to be reinforced and to inject a metered dose of molten thermoplastic synthetic material.

Subsequently, the object, for instance a fastening aid, a component part or a product, is arranged by hand or mechanically. Through the choice of materials, it can be effected that a good bonding between the object and the rest

of the core material is obtained. In known methods of reinforcing sandwich constructions, bonding to the top layers, in particular, may leave much to be desired.

For carrying out the present method, conventional injection molding machines can be used. To the extent necessary, an adjustment can be effected so as to bring the nozzle to the proper place for the injection. It is also possible, however, to use modified equipment, for instance injection molding machines enabling injection of the plastic material directly into the core material. For this purpose, for example, use can be made of an apparatus comprising a kind of "needle-shaped" injection nozzle, which is introduced through the top layer into the core. It is also possible to use nozzles provided with more than one outlet opening, so that more than one plastic material can be utilized.

When relatively high injection pressures are used, it may be desirable that the sheet-like material be supported at the back, i.e., the side where no injection takes place, so as to prevent the plastic material from being injected through the sheet.

It is also possible to inject the thermoplastic synthetic material from two sides of the sandwich material, for instance simultaneously or with a short interval.

The thermoplastic synthetic material is dosed depending on the nature of the material, the desired reinforcement in the core and the thickness of the sandwich construction. However, it has been found that the quantity is not very critical. For a sandwich construction of a thickness of 8 mm, a dosage of 0.5-20 ml of plastic material can be utilized. A good local reinforcement is then obtained.

According to the invention, modified sandwich materials are obtained which are suitable for various applications. One could think in particular of all kinds of objects which are useful in the air and space industry. Examples include wall panels of aeroplanes, component parts of aeroplane chairs, component parts of trolleys and the like.

The objects to be arranged may differ strongly. In the first place, inserts can be arranged, such as screwed bushes or other anchoring points. It is also possible to arrange forming blocks which may or may not be removable. These forming blocks can be provided on the same side where injection took place. It is also possible to mount the object from a lateral side.

The object may also be an aid onto which a product can be injection molded. This may take place at the top, but also at the sides or at the bottom.

The method according to the invention is applicable to flat sheet-like materials, but also to sheet-like objects already shaped. It is also of importance here that the reinforcement and the object generally have no influence on the further processability and deformability of the sheet-like material. This is of great importance for the thermoplastic sandwich constructions of the European patent applications mentioned, whose major advantage is in fact that they continue to be thermoplastically deformable. The manufacturing and processing methods described in the European patent applications mentioned in the introductory part of this specification can be applied without any problems to the materials according to the invention, both before and after the arrangement of the object.

Examples of objects that can be provided include threaded bushes, hinges, pivots, and the like.

The invention will now be illustrated in and by an example, but is not limited thereto.

Example

A sandwich panel consisting of a foam core of polyether imide with a specific gravity of 90 kg/m^3 and two top layers of glass fiber web (107 g/m^2), impregnated with polyether imide (50%), and 5 mm thick, was provided with a reinforcement. This was effected by injecting molten polyether imide through the top layer by means of an injection molding nozzle. The

sandwich panel was supported on one side thereof by means of a metal plate, while on the other side the injection nozzle was positioned against the surface of the top layer. The injection nozzle was provided with a surface extension. Through the force of the injection, the material was injected into the core with an injection period of 2 seconds.

A threaded bush of room temperature was subsequently placed in the still plastic material of the reinforcement.

The reinforced surface obtained had a diameter of 30 mm. The compression strength at the place of the reinforcement was 170 N/mm^2. The compressive strength of the panel itself was 3 N/mm^2. The extraction value of the threaded bush was 240 kg. A similar threaded bush, provided in a reinforcement which had already hardened, yielded an extraction value of 160 kg.

C L A I M S

1. A method for modifying a sheet-like sandwich material comprising a core material provided between two top layers, wherein under pressure an amount of thermoplastic material is injected through one of the top layers into the core material, an object is placed in the still plastic material, whereafter the plastic material hardens.

2. A method according to claim 1, wherein the object is an insert, a fastening aid, a component part, or a product.

3. A method according to claim 1, wherein the object is removed during or after hardening.

4. A method according to claim 1 or 2, wherein the object, at the time of its arrangement in the plastic material, has a temperature which is lower than the temperature of the plastic material.

5. A method according to claim 4, wherein the object has a temperature which is not higher than 75°C, more particularly, not higher than 35°C.

6. A method according to claims 1-5, wherein the object consists wholly or partly of metal.

7. A method according to claims 1-6, wherein, as thermoplastic material, a thermoplastic synthetic material is used, having a softening temperature of at least 50°C.

8. A method according to claims 1-7, wherein the thermoplastic synthetic material to be injected is selected from the group consisting of polystyrene, styrene polymers, acrylate and/or methacrylate polymers, polyolefins, polycarbonate, polyether imide, polyamide, polysulfone, polyether sulfone, polyether ketone, polyether ether ketone, polyether ketone ketone, polyphenylene oxide, polyphenylene sulfide, and mixtures of two or more of these materials.

9. A method according to claims 1-8, wherein the thermoplastic synthetic material to be injected also contains fibers.

10. A method according to claim 9, wherein the fibers are selected from the group consisting of glass fibers, polyamide fibers, such as aramid fibers, polyethylene fibers, polyester fibers and carbon fibers.

11. A method according to claims 1-10, wherein the core material is a synthetic foam which may or may not be thermoplastic or a honeycomb material which may or may not be thermoplastic.

12. A method according to claim 11, wherein a thermoplastic foamed core material is used, which is selected from the group consisting of polyether imide foam, polycarbonate foam, polymethacrylamide foam, polyester foam, such as a foam of PET or PBT, polyether sulfone foam, polyether ketone foam, polyether ether ketone foam, polyether ketone ketone foam, polyphenylene oxide foam, polyphenylene sulfide foam, or a foam material made of mixtures of thermoplastic synthetic materials incorporating at least one of said thermoplastic synthetic materials.

13. A method according to claim 11 or 12, wherein the thermoplastic foamed core material also contains fibers.

14. A method according to claim 13, wherein the fibers are selected from the group consisting of glass fibers, polyamide fibers, such as aramid fibers, polyethylene fibers, polyester fibers and carbon fibers.

15. A method according to claims 1-14, wherein, as top layer, a thermoplastic synthetic material is used, which synthetic material is reinforced with fibers, preferably in the form of a woven fabric, a knitted fabric, a fibrous web or unidirectionally applied fibers.

16. A method according to claim 15, wherein the thermoplastic material of the top layer is selected from polyester, such as PET and PBT, polycarbonate, polyether imide, polyamide, polysulfone, polyether sulfone, polyether ketone, polyether ether ketone, polyether ketone ketone, polyphenylene oxide, polyphenylene sulfide are mixtures of two or more of these synthetic materials.

17. A method according to claim 15 or 16, wherein the material of the reinforcement in the top layer is selected from glass fibers, polyamide fibers, such as aramid fibers, polyethylene fibers, polyester fibers and carbon fibers.

18. A sandwich material provided with an object or an opening obtained by the use of the method according to one or more of claims 1-17.

INTERNATIONAL SEARCH REPORT

International Application No PCT/NL 93/00088

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 B32B5/28; B32B3/08; B29C67/18

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	F16B ; B29C ; B32B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category[10]	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	EP,A,0 383 409 (SCHREINER LUCHTVAARTGROEP B.V.) 22 August 1990 cited in the application	1,2,6-18
A	see column 2, line 39 - column 3, line 30 see column 6, line 57 - column 7, line 6; claims	3-5
X	FR,A,2 395 823 (MESSERSCHMITT-BOLKOW-BLOHM GESELLSCHAFT) 26 January 1979 see page 1, line 1 - line 8 see page 6, line 17 - page 7, line 4; claims; figure 12	1,2,8, 11,15-18
A	NL,A,6 909 154 (SHUR-LOK CORPORATION) 4 May 1970 see page 8, line 15 - page 9, line 8	1

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
16 AUGUST 1993	27.08.93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	DE JONGE S.J.P.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US,A,4 729 705 (HIGGINS) 8 March 1988 see the whole document ---	1
A	DE,A,2 834 237 (MESSERSCHMITT-BÖLKOW-BLOHM GMBH) 13 September 1979 see the whole document -----	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

NL 9300088
SA 74148

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
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